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Industrial safety in explosive work environment view for Hungary

[1]Lajos Kiraly, [2]Agoston Restas

[1] National University of Public Service, Doctoral School of Military Science, Budapest, Hungary; [2] Institute of Disaster Management, National University of Public Service, Budapest, Hungary. Corresponding author: A. Restas, Restas.Agoston@uni-nke.hu

Abstract. To work safely in the chemical industry, it is necessary to ensure an appropriate work environment (including a fire protection system) that complies with the requirements for the used hazardous substances and also, to make the internal regulations and work instructions ready. This is especially applicable in case of operations performed with explosive materials - creating a safe work environment with potentially explosive substances. To determine a potentially explosive work environment, there is a calculation method fixed in the standards, which is partly passed on the objective judgment of the expert, a professional. Once the potentially explosive work environment is determined, the requirements for used equipment, machines and the conditions of working - depending on the zone classification - are clearly defined in standards and legal regulations. It also shows the importance of the topic, that the cost of work (including the cost of certified machines and equipment) in a potentially explosive work environment is multiple if we compare it with working in normal and standard work conditions.
Key Words: potentially explosive environment, risk, ATEX, fire.

Introduction. The engineering experience shows that the explosion safety, as one of the key parameters at the design, is an area which has not been adequately treated and understood in the industrial practice. The primary problem is that that the students of Bachelor engineering courses, do not get in touch, not even tangentially with subjects dealing with explosion protection. This is moderately true for the training of firefighters also (Bleszity et al 2014), who are supposed to prevent an explosion which has not occurred yet, or who arrive to the scene after an explosion to mitigate the damages. The firefighters' wide range educational material contains only a tangential knowledge related to explosions (Restás 2014), and also, the training of fire prevention specialists might be expanded by some areas of knowledge (Beda & Kerekes 2006; Kerekes 2014). That is why, in many cases, the professionals working in executive positions do not take into account the parameters connected with risk of explosion, while having regard to the danger and harms of the hazardous substances in the working area (Balázs & Lublóy 2010; Lublóy et al 2015). The aim of this article is to give a short and comprehensive picture of the perspectives of professional challenges for Hungary.

Relevant legal regulations. In order to prevent an explosion, very strict rules of technical requirements apply to equipment used in areas with explosion hazard. The Act XCIII of 1993 on Labour Safety – in agreement with the Minister for Social and Family Affairs and the Minister for Health – determines the rules for work equipment, and the minimum level work safety requirements for workplaces, including rules for the construction works with temporary or changing workplace (Legislation 1).

Based on the above authorization, the Minister for Agriculture together with the Minister for Social and Family Affairs and the Minister for Health constituted the joint regulation about the minimum work safety requirements for workplaces with potential risk of explosion, No. 3/2003 (III.11).

The regulation defines the concept of an explosive atmosphere and an environment with potential risk of explosion, according to which:

- explosive atmosphere: is such mixture of flammable gases, vapor, mists (aerosols) or dusts and air, that in case of fire - under normal circumstances - the flame spreads to the entire mixture;
- environment with potential risk of explosion: is that part of the workplace where explosive atmosphere might occur (Legislation 2).

According to the Section 9 of the above regulation, the employer has to prepare a documentation of explosion protection, including the risk assessment and evaluation and also the classification of workplaces into zones.

Criteria of the risk assessment. It is the duty of the Employer to identify - within the risk assessment procedure - the anticipated risks as far as the work safety and health at work is concerned. The risk and its range shall be determined by taking into account the followings:

- probability of incendiary effect in the explosive atmosphere, including electrostatic discharge;
- the probability of development and subsistence of an explosive atmosphere, and its duration;
- the range of anticipated impact in case an explosion occurs;
- equipment, used materials, procedures and their possible interaction.

Closed spaces, where explosive atmosphere might occur and which are connected with spaces with potential risk of explosion by windows and doors, must be also considered in term of risk assessment (Legislation 2).

If an explosion occurs, the injury can be defined in different ways. By the assessment of the individual injury, we suggest to take into account the overpressure rate at which the tympanic membrane breaks. In case of explosion, the approach of probit function cannot be used to determine the individual risk (Vass 2006).

Criteria of zoning. Earlier the Hungarian Standard, called MSz 1600/8:1977, dealt with the electrical danger of spaces with risk of explosion. The Hungarian Standard (MSz) No 15633-1:926 was the first, which formulated the potentially explosive space based on the EN standards, and this standard was fully included in the Regulation No 2/2002 (I.23) Appendix 4, chapter IX of the Ministry for Internal Affairs. The classification of areas with the hazard of explosion was the part of fire safety regulation until 2004 (Bónusz 2006).

After joining the European Union, the international regulations - Directive 94/9/EC of the European Parliament and the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres - were built into the Hungarian system of laws and the requirement of zoning was included in the joint regulation No. 3/of 2003 (III. 11).

The Employer shall classify its working spaces, where explosive atmosphere might develop into one of the following zones (Legislation 2):

- zone 0: a working space, in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapors or mist (aerosols) is present continuously or for long periods or frequently;
- zone 1: a working space in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapor or mist (aerosols) is likely to occur in normal operation occasionally;
- zone 2: a working space in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapor or mist (aerosols) is not likely to occur in normal operation but, if it does occur, will persist for a short period only;
- zone 20: a working space in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently;
- zone 21: a place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally;
- zone 22: a place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

The zoning of working areas is the analysis and classification method of such circumstances, where explosive gases may occur. Its target is to facilitate the selection and installation of electrical apparatus operating safely in such areas. The classification takes into account the ignition characteristics, the ignition energy (gas group) and the ignition temperature (temperature class) of the gas or vapors.

Besides the classification of the area and the danger zones, it is necessary to mention the education or training required for the classification:

- specialized engineering degree (chemical, mechanical, electrical, mechatronics);
- degree of higher education specialized in fire protection;
- degree of higher education in work safety;
- authorization to act as a regional work safety expert.

Recommmended process of risk analysis. Several methods can be used when conducting a risk analysis. The risk assessment methods used in safety documentations are the followings (Cseh 2005):

1. Facility selection method (according to CPR 18E - Purple Book – so called „Dutch filter");
2. Dow Fire and Explosion Index (TRI);
3. Checklists;
4. Preliminary hazard analysis;
5. Hazard and operability study (HAZOP);
6. Failure mode and effect analysis (FMEA);
7. Failure mode analysis, effects and criticality analysis (FMECA)/Risk matrix;
8. Fault tree analysis;
9. Event tree analysis;
10. Probability analysis by Monte Carlo simulation;
11. Analysis of Domino effect with DominoXL code;
12. Models of spreading impacts (consequence analysis).

Regardless of the methods, the general principle of the process to be followed is (Cimer & Dancsecz 2010) (Figure 1):

1. During the analysis of the technology and workflow, the possibility of developing an explosive area shall be determined;
2. The presence of ignition sources in the area have to be assessed;
3. The circumstances where an explosion evolves have to be determined;
4. The risks must be assessed based on the consequences of an explosion.

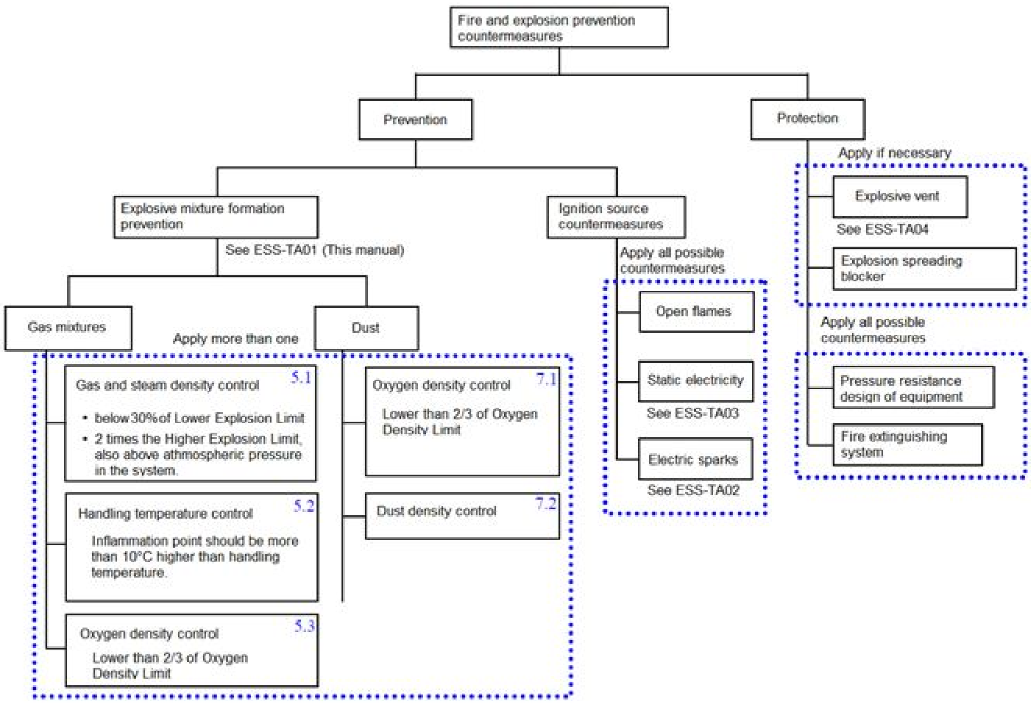

Figure 1. General process of risk analysis and prevention (Cimer & Dancsecz 2010).

The work process proposed five interrelated steps (Sankar & Prabhu 2001):

1. The first step of the process is the technology and workflow analysis with the internationally recognized and used Failure Mode and Effects Analysis method. The aim of the method is to determine the possibility and probability of forming an explosive atmosphere, thereby narrowing and focusing the analysis from the whole company to the critical areas. The method must be adapted to the analyzed system.
2. The second step of the process is to survey and assess the present and potential sources of ignition in the area of the potential "scenarios" revealed in the first step.
3. Then the weaknesses revealed during the technology and workflow analysis shall be ranked.
4. Analysis of the impact of the explosion on the workers (overpressure) with explosive blast pattern calculation and explosion simulation software.
5. The results of the risk analysis, and the suggestions to suppress or decrease the risks based on the FMEA analysis data sheet.

Preventive countermeasures for explosive mixture forming of flammable gas and steam

Density control in case of an open system. In case of handling flammable gas or liquid transfer, sampling, coating, etc. in an open system, where flash point of said gas or liquid is lower than handling temperature, there is a hazard for explosive mixture formation from explosive gas or steam in the area, so we need to apply the following countermeasures (Szakál 2001; Eckhoff 2005):

- preventing the congestion of flammable gas and steam with natural ventilation. When handling flammable gas or liquid outside, make sure the handling place has good natural ventilation, so that the flammable gases and steam won't congest;
- preventing the congestion of flammable gases and steam with forced ventilation. When handling flammable gases and liquids inside, such as in an establishment, equipment, or any place between four walls, where the natural ventilation is bad, use a local exhaust device which has the capacity for the appropriate air flow and air pressure, and has an explosion-proof construction, to keep the density below 30% of the Lower Explosion Limit. Furthermore, if the flammable liquid is falling under the Ordinance on Prevention of Organic Solvent Poisoning of the Industrial Safety and Health Law, other than for explosive mixture formation preventive countermeasures, use local exhaust devices that comply with the usage classification of the organic solvent, to prevent health impairment.

Density control in case of industrial dangerous material dryer. Drying solvents used for coating, and the like, in an industrial dryer, the solvent generates steam and has a hazard of forming an explosive mixture, so forced ventilation is needed to keep the generated steam density below 30% of the Lower Explosion Limit. Also, as necessary safety equipment in case the ventilation equipment stops to function, set an interlock, to stop the dryer and restrain the solvent's steam based on ventilation system stoppage signal or flammable gas sensor upper limit alarm (Szakál 2001; Eckhoff 2005).

Control based on Upper Explosion Limit density. In case the flammable gas or steam is stored in an airtight container, the density of the flammable gas or steam should be at least twice as the Higher Explosion Limit, while inside pressure of the system needs to be above atmospheric pressure. Furthermore, when the airtight container gets opened, there is a hazard for explosive mixture formation, so make sure you do a thorough assessment. There is a precedent of workers dying in a fire accident where they opened a gasoline tank, wore an oxygen mask, and entered to work inside the tank (2003 August, ExxonMobil) (Szakál 2001; Eckhoff 2005).

Leakage preventive countermeasures. If flammable gas or liquid leaks, it can lead to the formation of explosive mixture. Apply the following leakage preventive countermeasures (Szakál 2001; Eckhoff 2005):

- in case of piping, valve, gauge and other joint parts, pump shaft sealing parts, where the flammable gas or liquid can leak easily, do daily inspection, and in case a problem is found, immediately deal with it, applying leakage prevention;
- when there is a periodic inspection in the establishment or equipment where flammable gas or liquid is handled, carefully examine if there are any cracks, rust, or other abnormal situation that can lead to leakage;
- be careful not to control the valves with too much power;
- when filling up, or transferring flammable liquid, make sure to observe the surface so it doesn't overflow;
- when opening up an establishment or equipment that handles flammable gas or liquid, for example to repair it, before doing so, check if there is any residual gas or liquid inside, and if there is, remove it;
- to prevent a widespread leakage in establishments where leakage can easily happen, set outlets, pits, or something that can catch it;
- in establishments and equipment, where leakage of flammable gases or steam can easily happen, make sure to find the leakage early, by installing a leakage detection device, and/or by controlling the amount you handle or use;
- in establishments and equipment, where there is a high hazard of accidents happening because of flammable gas or liquid leakage, install a leakage detection device, and preparing for the worst case, install emergency shutdown system in case there is a leakage.

Main foundation elements for risk calculation methodology

Photochemical ignition. If the radiant energy of quantum energy big enough, it is able to initiation of throttle response. Example: at the illumination of hydrogen and chlorine, convert for hydrochloride (explosively).
Blue or violet and ultraviolet light causes the formation of explosion (more than 243 kJ energy), the fewer wavelengths is not. There are known many photochemical reactions, But the photochemical ignition in the practices of safety and fire prevention is subordinate

Auto-ignition, pyrophoric. The auto-ignition temperature is the lowest temperature at which ignites and burns a self-sustaining manner, without an external ignition source of the material (Faghih et al 2016).

Electrostatic ignition source. The materials electrically are neutral in original condition. The material is made up of positively and negatively charged particles. These are the charge carriers which are located inside both materials and on surface an equal number and uniformly distributed.

Weak point analysis. The scopes of critical risk assessment are the following:

- failure specifying: cause of system failures-accident;
- quantities analysis: explosion risk investigation – by on effect, risk, countermeasure, reduce amount of risk.

Modelling. Explosion pressure: increasing pressure against atmospheric pressure (normal) - caused by weapons and explosives (Compression of the explosion wave heats the molecules of air). Calculation methods defined by MSZ EN 60079-10-1:2009, effective areas could be defined with using of software. Defining of Zone areas: using software modelling tools - defining lower and higher burning/explosion levels. For countermeasures have to define the pressure levels and effects (Bogacskó 2016).

Risk assessment, reduce the amount of risks. Scope: explosion effects against human body and calculating relevant chance of explosion (against operating, engineering failures, etc.). Have to install hardware tools against explosion risk areas (explosion proof equipment) - responsibility of the employer.

Criterions of working environment and the minimum levels of working conditions. The explosion-proof of technology processes has to be granted by explosion prevention, explosion protection, organizational and technical measures. The presence of ignition source has to be excluded in order to prevent explosions and generating of explosive aerospace.

The general requirements of electrical equipment using in explosive aerospace are the following: The electrical equipment on the main components has to be marked with the following information in clearly visible and corrosion-resistant manner:

- manufacturer name and address;
- type ID;
- "Ex" mark;
- used protection method;
- group sign, sign of temperature class, "G" mark (explosive aerospace caused by gases, vapours or fog);
- serial number;
- name and sign of the certificate issuer, certification ID;
- the CE mark.

Operating manual has to be enclosed to the equipment that has to be include the following written instructions:

- information about the equipment mark;
- safe conditions of using for the commissioning, usage, assembly and disassembly, maintenance, installation and setup;
- rules for operator trainings;
- detailed information in order to decide that the usage of equipment is safe or not in the specified area with expected operating conditions;
- the maximum surface temperature and other limits;
- the special conditions of use;
- the relevant characteristics of tools used for equipment;
- the list of the standards which prove the product satisfying.

Hypoxia prevention. Hypoxia is the situation, where oxygen density doesn't reach 18%. When work is being done inside the inert gas sealed tank, apply hypoxia prevention accordingly to the Industrial Safety and Health Law Ordinance on Prevention of Hypoxia.

In case work is being done inside an opened inert gas sealed equipment, the master valve has to be closed, the pipe has to be removed, and the upstream side has to have a stoppage plate installed (if it is impossible, insert a diaphragm into the flange) to separate it from the system, and hypoxia prevention has to be applied at local exhaustion.

In case of indoor inert gas sealed equipment, apply preventive countermeasures against hypoxia by leakage.

Conclusions. It is important to treat the above described area of expertise as a matter of high priority, because the inherent risks in the individual substances (chemicals) are not always known. Likewise, we do not have the necessary knowledge about the mixtures and powders/hybrid powders used in the chemical industry. The approach in each case is based on in-depth planning. The revision of the planned process (P&I and HAZOP), taking into account the properties of the materials to be used there (risks of fire and explosion) is of high importance. In the planning phase, there is a possibility to reduce the dangerousness of the materials (by using additives – inhibition), this way the technological processes may be improved and rationalized. In case the realization of the previously described is not possible, getting to know the explosive parameters of each substances and further tests (measurements) in case of mixtures become important. Otherwise, the engineering estimation may be used, which is conservative in every case, and it certainly increases the cost.

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Authors:
Lajos Kiraly, National University of Public Service, Doctoral School of Military Science, Budapest, Hungary, e-mail: lajos.kiraly@gmail.com
Agoston Restas, Institute of Disaster Management, National University of Public Service, Budapest, Hungary, e-mail: Restas.Agoston@uni-nke.hu
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